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Abstract. Detailed palynological studies in two adjoining French Pyrenean valleys, complemented by the study of archives, demonstrate that under similar climatic conditions, the forest history of each valley from the Bronze Age to present time was essentially determined by socio-economical constraints, possibly modified by natural characteristics such as topography. The studies show why the expansion of *Fagus* (beech) at c. 4000 B.P. was asynchronous on the northern slope of the Pyrenees and emphasize the effects of the human impact on the recent lowering of the tree-line.

Key words: Human impact – Natural characteristics – Socio-economic constraints – French Pyrenees

Introduction

The forests of the northern slope of the Pyrenees, particularly those of the eastern half, have been subject to human influence for many millennia. The first evidence for this influence is observed at c. 6200 B.P. in pollen diagrams from the Mediterranean Pyrenees, in Pays de Sault and the Aude valley (Vernet 1980; Jalut and Vernet 1989; Reille 1990a). Though it is characterized by low levels of anthropogenic indicators, it is complemented by archaeological evidence and, especially, records of domestic fauna (Geddes 1980, 1987). At that time, the zone of influence was probably such that human impact on the forest of the high Aude valley (above 1300 m) can be expected.

Despite these observations, neither anthropogenic pollen indicators nor changes in the composition of the forest cover suggest large phytogeographic modifications in the Ariège and Mediterranean Pyrenees between 6000 and 4000 B.P. *Abies* (fir) remains the dominant tree between 2000 and 800 m and at probably lower elevations in some places (Jalut et al., in press). At lower elevation, *Quercus* (oak) forest was dominant while *Pinus uncinata* forms the subalpine forest above 2000 m.

As is known for many years, the post-glacial expansion of *Abies* always occurs before that of *Fagus* (beech) in the Ariège and the Mediterranean Pyrenees (Jalut 1974). The first records of *Abies* pollen have been dated to 9800±100 B.P. at Nohèdes (1680 m; Jalut 1974) and 9150±250 B.P. in the same valley at Gourg Negre (Reille 1990b). In these areas, the beginning of its expansion is dated at many sites to between 8300-8200 and 7000 B.P. (Jalut et al. 1982, 1988; Reille 1993a) but it is later in the western part of the Pyrenees (around 4650-4300 B.P.; Jalut et al. 1988).

Fagus pollen can be regularly present but it remains rare between 5000 and 4000 B.P. and its general expansion begins around 4000 B.P. (Jalut 1984). Climate has been regarded as the determining factor in the development of beech forests at c. 4000 B.P. (Jalut 1974) but it has also been demonstrated that human influence may have been responsible for its strong expansion at this time (Kenla and Jalut 1979; Jalut 1984).

At about 4000 B.P. human impact is recorded throughout the northern and southern slopes. The first description of human impact and its consequences for the fir forests was based on investigations at Etang de Lhers in Ariège (Kenla and Jalut 1979). Later, overall schemes were proposed for Ariège and the Mediterranean Pyrenees (Jalut 1984; Jalut et al. 1982), for the western French Pyrenees and for some sites on the western Spanish slopes (Jalut et al. 1982, 1988; Monserrat i Marti 1991).

Human impact on the fir forest favoured either an increase in beech abundance leading to mixed forests in which beech was frequently dominant at medium and low altitude, or resulted in a decrease in *Abies* and the extension of *Pinus uncinata* as observed between 1600 and 2000 m altitude in the eastern Pyrenees (Jalut 1984) and in the Quioules valley (present paper). When the human impact was too strong fir was totally cleared, e.g. in high altitude valleys of Nohèdes and Tech (Mediterra-

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nean Pyrenees, Jalut 1974), and also in the mountain and subalpine forests, e.g. in Vicdessos and Massif of Ossau (Western Pyrenees) (Jalut et al. 1982, 1984).

During the Roman and Middle Ages, the dominance of beech continued. The destruction of the fir forests and the dominance of coppices of beech during the 18th century were confirmed by Louis de Froidour (Fruhauf 1980, 1986, 1990). With the increased demand for metals during the 18th century, wood and particularly charcoal was in much demand (Bonhote and Vernet 1988; Davasse and Galop 1990; Davasse 1991; Galop 1992; Bonhote 1993). Rapid and large scale destructions occurred and, in many places, sheep breeding contributed to the destruction of the forest. When forest management was established during the reign of Louis XIV, some areas were specifically chosen for fir cultivation (Pays de Sault), while beech was progressively destroyed or limited to zones of higher altitude. On the other hand, other areas containing beech of economic value were preserved (Fruhauf 1980).

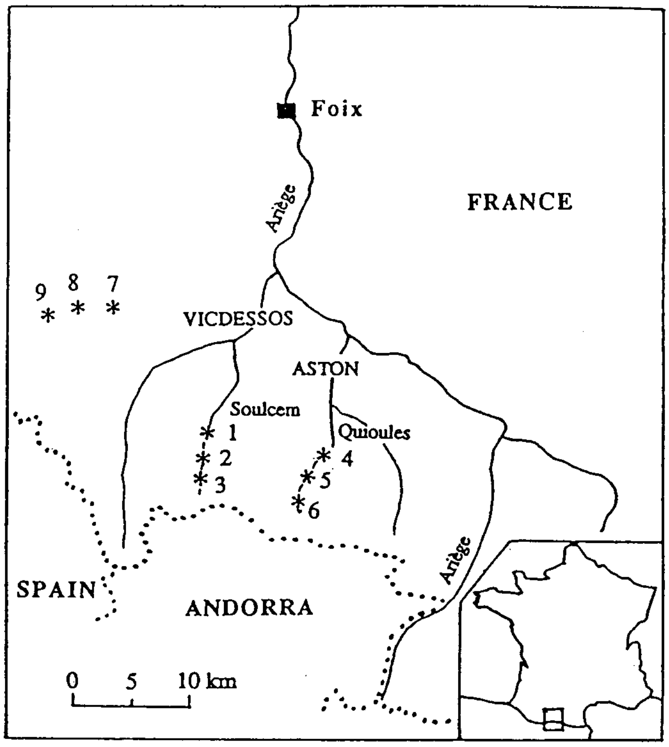
During the last five years, pollen analytical investigations were again carried out by Reille (1990a,b, 1993a,b; Reille and Lowe 1993) on the sites already studied in Ariège and the Mediterranean Pyrenees as well as in the central and western parts of the chain, and sometimes even at the same coring site (Freychinede 1, Reille 1993a, b). These have provided comparable data concerning human impact and have confirmed the previously published results. A substantive improvement in the reconstruction of the past environments is more likely to come from the study of additional sites and the availability of ^{14}C dates obtained from thin sediment layers.

The new detailed studies show that substantial differences can be seen within the same region between the forest history of neighbouring valleys where obviously similar climatic conditions prevailed. This is well illustrated here by reference to new investigations carried out in the valleys of Soulcem and Quioules which are now considered.

Description of sites, including present-day vegetation

The valleys of Soulcem and Quioules belong to the high Ariège basin (Fig. 1). These are glacial valleys of northern exposition. The valley of Soulcem, 12 km long, is a branch of the Vicdessos valley. The bedrock consists mainly of metamorphic schists of Palaeozoic age. The valley of Quioules, which is incised in a granite zone, is a branch of the Aston valley on the west side of the Ariège river. Facing north, but sheltered by the Pyrenean northern front, the two valleys have an oceanic climate which shows some degree of continentality (Dupias 1985). The climatic regime is favourable for the development of mountain forests with *Fagus sylvatica*, *Abies alba* and *Pinus uncinata* (Gaussen 1964).

In each valley, at various altitudes between 1600 and 2000 m, flat surfaces called *pla* are present. They correspond to former basins infilled with more or less coarse late-glacial or Holocene detritic material and colonized by dense *Nardus stricta* meadows with, on the driest places, *Calluna vulgaris*. Peaty areas have also frequently developed.



1. Pla de Soulcem, 2. Pla de Labinas, 3. Pla de Croutz, 4. Jasse de Ranques 5. Pla du Quioules, 6. Pla de la Sabine, 7. Freychinède, 8. Etang de Lhers, 9. Argentières

Fig. 1. Map of the study area

Considerable differences exist between the vegetation cover of the two valleys. In the Soulcem valley, only the lower part is forested up to about 1400 m (Fig. 2). The dominant species are *Betula*, *Quercus petraea* and *Fagus* which extend up to the present-day forest limit. Above 1400 m, the slopes as well as the flat areas are completely deforested so that *Abies*, *Fagus* and *P. uncinata* are absent. Instead, meadows and heaths are the main vegetation types. On the other hand, the forest is well developed in the Quioules valley (Fig. 2). Between 1000 and 1500 m altitude, the succession from a *Q. petraea* to a *Fagus*-dominated forest can be observed, with much young *Abies alba* below the canopy which indicates the overall successional trend. Above 1500 m and up to 2300 m, *P. uncinata* dominates and continues to expand. Its presence at low altitude is consequence of the former forest changes. In the same altitudinal range, stands of *Abies* and *Betula pendula* appear as well as, in many places, *Rhododendron ferrugineum*.

Methods

Field techniques

To understand the differences in the vegetation cover, we have carried out several corings in the two valleys and we selected three sites in each valley for detailed study.

In the valley of Soulcem, the sediments in Pla de Soulcem were sampled before the construction of the present dam. The coring site was in a peat bog, which lay under 30 cm of water at the foot of the slope on the eastern side of the stream (42°40'10"N, 1°26'30"E). Several corings were made in this peat bog, along an east-west transect. Because of the presence

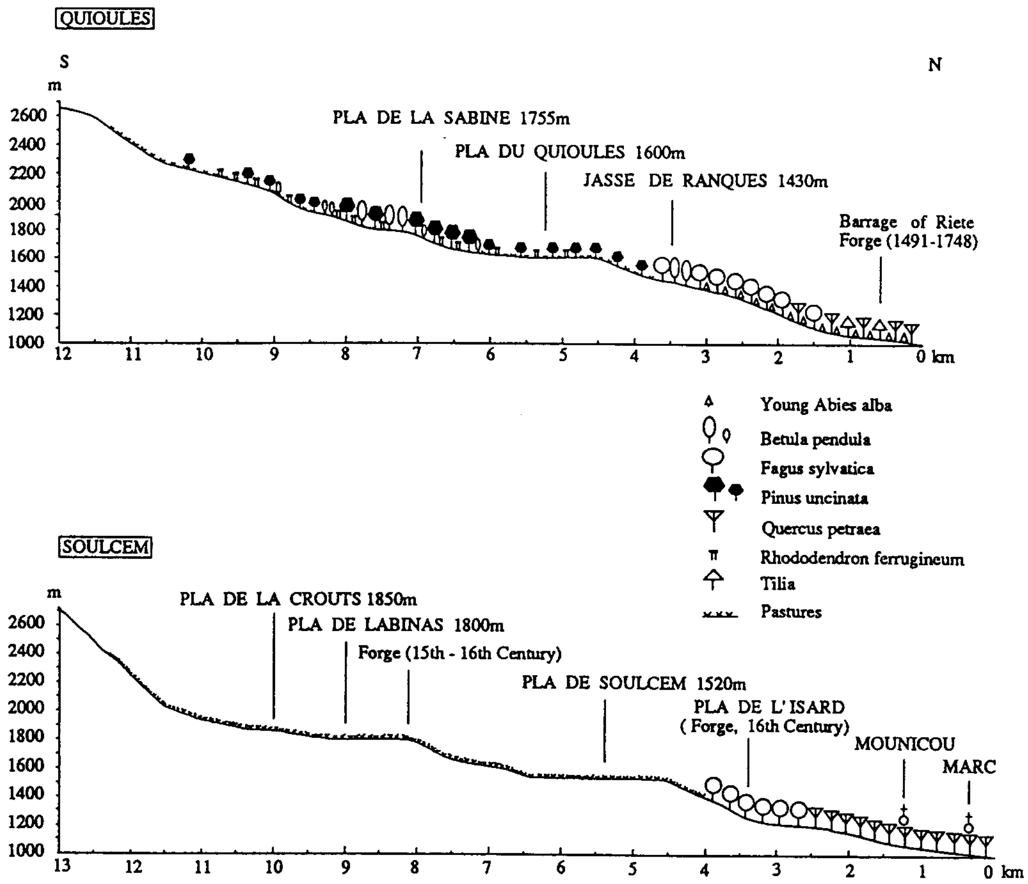


Fig. 2. Sketches showing the relationship of present day vegetation and pollen sampling sites to altitude in the valleys of Quioules and Soulcem

of water, the first 50 cm of peat were collected using a Hiller sampler; otherwise, a piston sampler of 40 mm diameter was used. At the sites Labinas (42°38'24"N, 1°26'30"E) and Croutz (42°37'37"N, 1°26'30"E) the sediment was sampled in the form of monoliths. In the Quioules valley, sampling was carried out using a Russian corer (Ranques: 42°41'10"N, 1°39'04" E; Quioules: 42°40'11"N, 1°37'57"E; Sabine: 42°39'36"N, 1°37'11"E)

Pollen counting

A total pollen count of more than 300 grains per sample was made, except in some layers poor in pollen. In many cases, especially in the profiles from Soulcem, Labinas and Crouts, counting was continued until a total of 400-1600 was reached. Furthermore, after pollen analysis, the slides were completely scanned to find the rare pollen taxa. The pollen concentration per gram was calculated according to the Cour's method (Cour 1974) but the results are not represented here. In the profiles from Pla de Labinas and Croutz, sampling was frequently carried out at intervals of between 3 and 0.5 cm to take account of changes in stratigraphy.

Results

Radiocarbon dating, zonation and correlation of the pollen diagrams

The results of radiocarbon dates, all from thin slices of sediment, are presented in Table 1. Calibrated age range at two sigma confidence limits were obtained using the calibration program of Stuiver and Reimer (1993, Mac Test version #7).

Only in the case of the peat profiles from the Quioules valley have estimates been made of ages using the depth-age ratio. For the uppermost levels, ages estimated on the basis of the ^{14}C results have been compared with the available historical data concerning major vegetation changes and local industry (presence of forges, local production of charcoal, etc.).

The major vegetation changes that have been used include olive cultivation and the regional introduction of *Juglans* and *Castanea*. The available historical and palynological data show that the cultivation of olive in Spain and the French Mediterranean coast of the eastern Pyrenees increased during the 12th century and decreased shortly before the 18th and 19th centuries (Bonassie 1990; Planchais 1985; Riera-Mora and Esteban-Amat 1994). Due to its abundant pollen production and dissemination, the pollen of *Olea* is an excellent chronological indicator (Galop, in preparation) which can be used here to good effect, particularly in the profiles from Soulcem.

The first occurrences of *Juglans* are well dated in Ariège (2020±90 in Jalut et al. 1982; 1850±50, Galop, unpublished). There are regular records from the 10th to the 13th centuries, though the dates may vary with area and altitude (1110±70 B.P. and 760±50 B.P., Galop, unpublished; near 700±70 B.P., Planchais 1985).

Concerning *Castanea*, its regional expansion occurs in the 18th-19th centuries. However, it was always very limited and essentially remained a tree of the piedmont.

Table 1. Radiocarbon dates from the pollen profiles

Site	Depth(cm)	Material dated*	^{14}C Lab. Ref. No. (Gif-)	Age (B.P.)	Calibrated aged (cal. A.D. (+); cal. B.C. (-))	$\delta^{13}C$ (‰)
Soulcem	130 - 140	CP	4385	1160 ± 90	+ 681 to + 1022	
Soulcem	172 - 182	CP	4587	2180 ± 90	- 394 to - 30	
Soulcem	240 - 250	SP	4386	3320 ± 100	- 1786 to - 1400	
Labinas	15.5 - 17.5	SC	4805	recent	-	
Labinas	29.5 - 30.5	SC	4806	330 ± 90	+ 1421 to + 1688	
Labinas	50 - 51	CP	4807	610 ± 90	+ 1246 to + 1458	
Labinas	64 - 65	CP	4808	1430 ± 100	+ 417 to + 817	
Croutz	19 - 20	SP	4809	500 ± 90	+ 1298 to + 1528	
Croutz	40 - 41	SC	4810	1960 ± 100	- 192 to + 260	
Ranques	29 - 31	P	8546	900 ± 90	+ 1000 to + 1283	-26.89
Ranques	59 - 60	P	8548	2740 ± 60	- 1000 to - 803	-27.70
Ranques	68 - 71	P	8747	3210 ± 70	- 1637 to - 1312	-27.75
Ranques	97 - 100	P	8550	5040 ± 70	- 3970 to - 3697	-27.85
Quioules	79 - 81	P	8746	650 ± 80	+ 1247 to + 1432	-27.45
Quioules	184 - 185	P	8553	3070 ± 70	- 1459 to - 1117	-27.66
Sabine	55 - 56	SC	8556	720 ± 220	+ 864 to + 1662	-26.09
Sabine	65 - 66	SC	8602	1230 ± 220	+ 417 to + 1239	-25.63

* for explanation of abbreviations see Fig. 3

The above information, rather than the ^{14}C-derived depth/age relationship, has been used in the case of the Soulcem valley profiles. In view of the frequent changes observed in the stratigraphy, this is considered a more reliable approach. However, in this case the presence and the changing concentration of black particles compared with the historical data concerning local charcoal production and forges, provide a further guide to dating major changes in the arboreal pollen/pollen sum (AP/T) ratio as well as in the sedimentological processes. Between the 13th and 17th centuries, the archives indicate increased charcoal production related to the development of metallurgy in the valley of Vicdessos. At levels in the pollen diagrams from Labinas (Fig. 4, between levels 34 to 21) and Croutz (Fig. 5) that correspond to this period, the representation of black particles rises sharply (Labinas, 29.5-30.5 cm, cal. A.D. 1421-1688; Croutz: 19-20 cm, cal. A.D. 1298-1528). The time span involved (c. cal. A.D. 1298-1688), closely corresponds to the period during when a forge was in operation between Pla de Soulcem and Pla de Labinas. The Soulcem profile also shows a clear correlation between layers with a high density of black particles and a decline in the AP/T ratio. It is concluded that the black particles in the sediments of these sites are charcoal. The presence of these particles in the basal peats at Soulcem indicates the early destruction of the local forest by burning.

Historical investigations

If we exclude the rare references dating to the Middle Ages, the first texts concerning the Pyrenean forests appear in the 17th century during the *Réformation des Eaux et Forêts* ordered by Colbert during the reign of Louis XIV. Accounts have become more numerous by the end of the 18th century. The reports written by the General Surveyor Louis de Froidour in 1669 on the Pyrenean forests as well as the various descriptions contained in the Forest Surveys, and the consular and council deliberations, enable the extent and composition of the forests and composition from the 17th onwards to be reconstructed in considerable detail. The original documents can be consulted at the Archives Center of Ariège. These have been used in the studies by Fruhauf (1980), Davasse and Galop (1990), Galop (1992) and Bonhote (1993).

On the basis of these complementary data, and using also the curves of local taxa such as *Calluna* and Rosaceae and the changes in the AP/T ratio particularly in the Soulcem profiles, the correlations of the various pollen profiles have been arrived at (Fig. 9).

The pollen diagrams

The profiles are divided into local pollen assemblage zones, defined by the proportions of the most important local and extra-local taxa. The pollen sum (T) includes pollen of trees, shrubs and herbaceous taxa except Pteridophyta and Cyperaceae, the last mentioned being considered to represent mainly hydrophyte species.

Pla de Soulcem at 1520 m in the Soulcem valley (Fig. 3). Charcoal particles were observed more or less throughout the core and were particularly abundant between

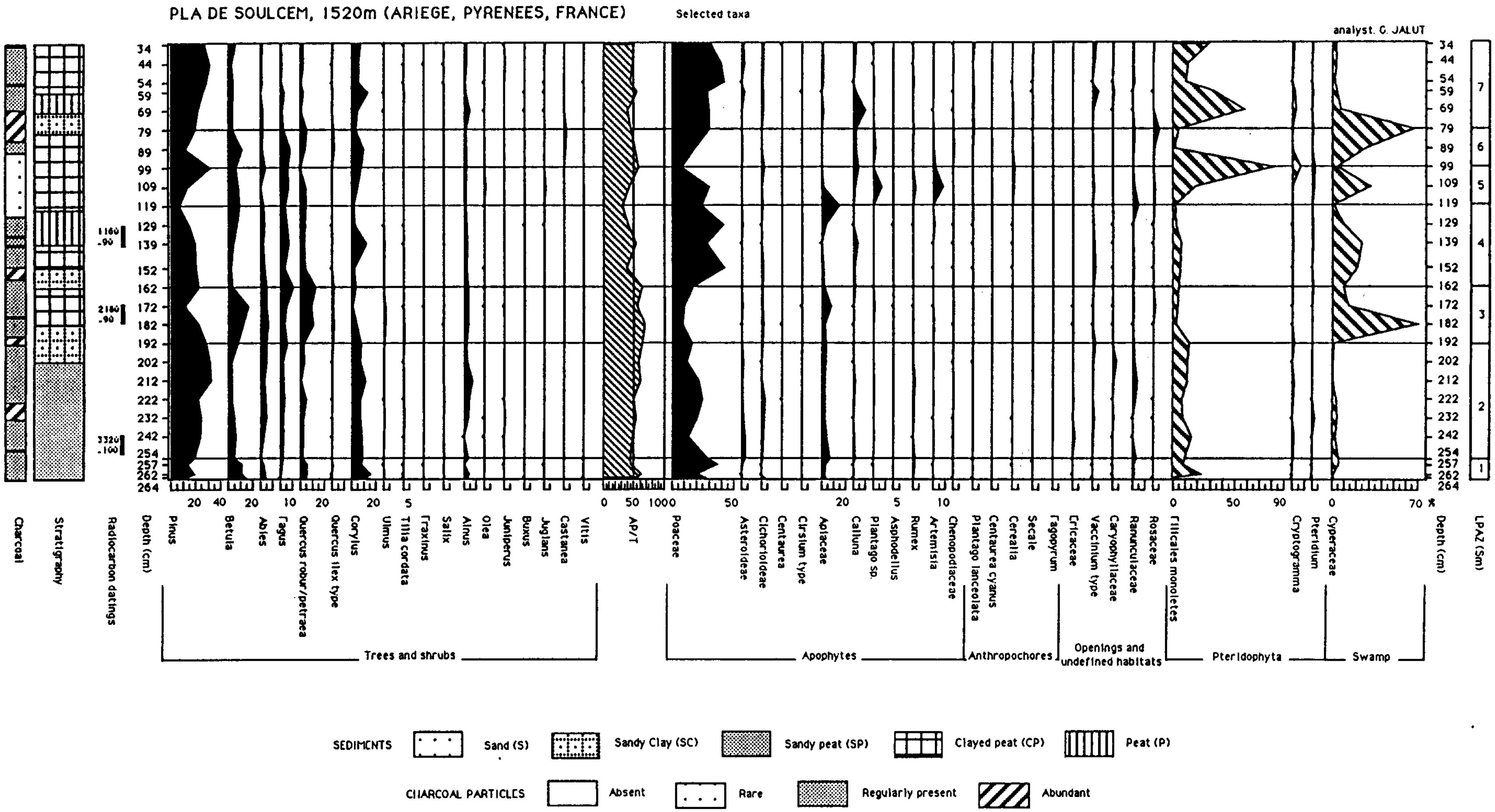


Fig. 3. Pollen diagram from Pla de Soulcem. In this and the other pollen diagrams, taxa shown as hatched curves are excluded from the pollen sum. Their representation is expressed as a percentage of the pollen sum. Curves for minor taxa are omitted

Table 2. Description of the local pollen assemblage zones in the profile Pla de Soulcem

LPAZ/ Depth (cm)	LPAZ name	Main features of the LPAZ
Sm7 34- 79	Poaceae-*Pinus-Calluna-Secale*	Increase in Poaceae and *Pinus* percentages. Presence of *Secale* and *Fagopyrum*.
Sm6 79- 99	Cyperaceae-Poaceae-*Pinus-Castanea*	Increase in Cyperaceae and Poaceae. Regular presence of Chenopodiaceae and *Castanea* with low values. Decline of *Fagus* and *Betula* at the end of the zone. *Upper limit:* fall in Cyperaceae, and presence of *Secale* and *Fagopyrum*.
Sm5 99-119	Poaceae-Cyperaceae-*Artemisia-Plantago*-Cerealia	Strong increase in Filicales. Continuous curve of Cerealia. Slight increase in *Rumex* and *Calluna*. At the end of the zone increase in *Pinus*. *Upper limit:* increase in *Calluna* and Cyperaceae, and presence of *Castanea*.
Sm4 119-162	Poaceae-Cyperaceae-*Pinus*-Cerealia	AP/T regularly lower than 50%. Regular occurrences of Cerealia and *Plantago lanceolata*. Beginning of the continuous curve of *Pteridium*. Slight increase in *Calluna* and presence of *Juglans*. Increase in Apiaceae at the end of the zone. *Upper limit:* Decrease in Apiaceae, and increase in Filicales, *Artemisia* and *Plantago* sp.
Sm3 162-192	Cyperaceae-*Pinus*-Poaceae-*Betula-Quercus-Fagus*	Fall in *Pinus* and *Corylus* and sharp increase in Cyperaceae. Substantial increase in *Betula, Quercus* and *Fagus*. *Upper limit:* increase in Poaceae, regular presence of Cerealia and decrease in *Quercus* and *Fagus*.
Sm2 192-254	*Pinus*-Poaceae-*Corylus*	Increase in *Pinus* and *Alnus*. Small fluctuation of the AP/T ratio around 50-60%. *Upper limit:* decrease in *Pinus*, Poaceae and *Corylus*, and increase in Cyperaceae.
Sm1 254-264	Poaceae-*Pinus-Betula-Corylus*	Poaceae dominant, *Corylus* at 10-20% and AP/T ratio at 40-60%. Presence of *Vitis, Juglans,* Cerealia and *P. lanceolata*. *Upper limit:* Decrease in Poaceae and *Betula*. Slight increase in Asteroideae and Apiaceae.

232-223 192-188, 157-150, 135-134, 84-68, 60-59 and 35-34 cm. Charcoal was poorly represented at 248-247, 177-178, 139-140 and 124-90 cm and was absent at 55-54 cm. Seven local pollen assemblage zones (LPAZ) have been recognised; these are described in Table 2.

During the period represented by the pollen diagram, the AP/T ratio indicates an open landscape in which the mountain trees (beech, fir, pine) seem poorly represented. This is particularly true for pine. Its low values in in Sm3 to 6 (between 5 to 30%) probably reflect large scale destruction of the pine forest in the valley. In this present treeless landscape, *Pinus* representation in modern pollen samples collected between Pla de Soulcem and Pla de Croutz lies between 33 and 17%.

Because of the favourable situation of the site near the footslope, it can be concluded from the low values of *Fagus* and *Abies* that the mountain forest was probably already cleared when sedimentation began. The regular occurrence of spores of *Cryptogramma crispa* reinforces this hypothesis. Noteworthy also is the good correlation that exists between phases with abundant charcoal particles and a decline in the AP/T ratio. Abundant charcoal during some phases may also indicate a substantial tree population. Zone Sm3 is a good example of a short-lived recolonization phase that abruptly stopped at 162 cm. Taking into account the dates from below and above the Sm3/4 zone boundary (2180 and 1160 B.P., respectively) and by comparison with the Labinas profile where the AP/T value is still at 50% around 1400 B.P., it can be assumed that this boundary (i.e. 162 cm) can be placed at c. 1400 B.P.

Pla de Labinas at 1810 m in the Soulcem valley (Fig. 4). In this profile charcoal particles are recorded from 50.5 cm to the surface. They are particularly abundant at 37.5-37 cm and between 34.5 and 21.5 cm. The pollen diagram is divided in seven LPAZs (Table 3).

The low AP/T ratio, the regular presence of anthropogenic indicators as well as pollen of *Calluna* and spores of *Cryptogramma crispa* indicate the existence of an open landscape during the period represented by the pollen profile. An abrupt change is recorded at 51.5 cm when the AP/T ratio decreases and becomes regularly lower or equal to 40%. This event, dated to 610±90 B.P.. (cal. A.D. 1246-1458) is correlated with the first occurrence of charcoal particles. The presence of pollen such as *Juglans* and Cerealia, the AP/T ratio and the radiocarbon dates suggest that the base of the pollen diagram correlates with the Sm3-Sm4 boundary (see above).

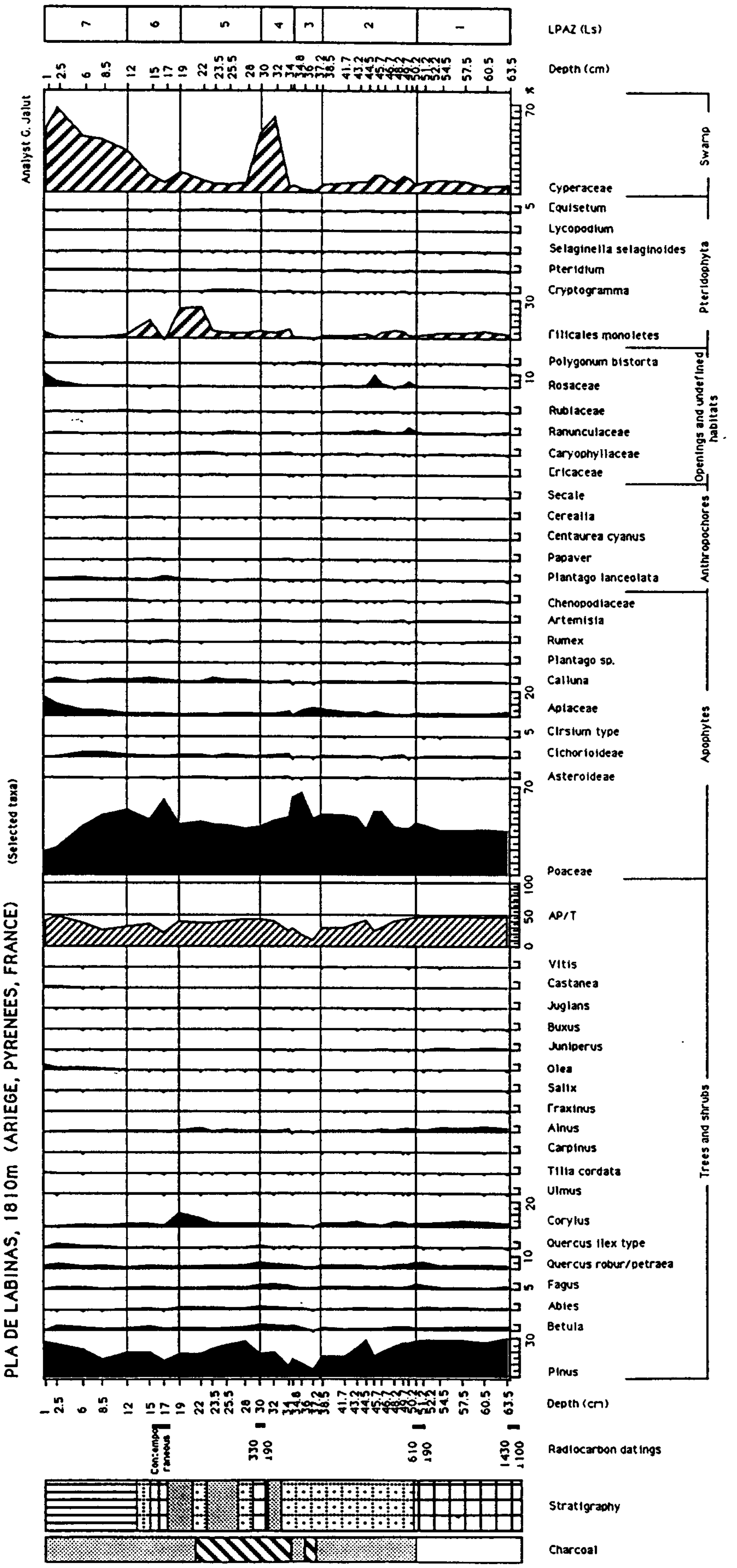


Fig. 4. Pollen diagram from Pla de Labinas

Table 3. Description of the local pollen assemblage zones in the profile Pla de Labinas

LPAZ/ Depth (cm)	LPAZ name	Main features of the LPAZ
Ls7 1- 12	Cyperaceae-Poaceae-*Pinus-Castanea*	Continuous curve of *Olea*, presence of *Castanea* and slight increase in Cichorioideae. At the end of the zone, increase in Rosaceae.
Ls6 12- 19	Poaceae-Cyperaceae-*Pinus-P. lanceolata*	Short and synchronous increase in Poaceae, *P. lanceolata*, *Rumex*, Rubiaceae and Rosaceae. Except for Poaceae the percentages stay low. *Upper limit:* fall in Poaceae, increase in Cyperaceae and presence of *Castanea.*
Ls5 19- 30	Poaceae-*Pinus*-Cyperaceae-*Calluna*	Moderated increase in *Calluna* and *Cryptogramma*. At the end of the zone, in 119-crease in *Corylus* and Filicales. *Upper limit:* fall in *Corylus* and Filicales, and increase in *P. lanceolata.*
Ls4 30- 34,5	Cyperaceae-Poaceae-*Pinus*	Strong increase in Cyperaceae percentages. Synchronous but minor increase in Cichorioideae, *Calluna* and Filicales. *Upper limit:* fall in Cyperaceae percentages, and increase in *Calluna* and *Cryptogramma*.
Ls3 34.5- 38.5	Poaceae-*Pinus*-Apiaceae-Cyperaceae	Lowest *Pinus* percentages and increase in Poaceae and Apiaceae. *Upper limit:* fall in Poaceae percentages, and increase in Cyperaceae and Filicales.
Ls2 38.5- 51.25	Poaceae-*Pinus*-Cyperaceae-Rosaceae	Decrease in the AP/T ratio and also in *Pinus* values. Gradual increase in Poaceae and small peaks in Rosaceae. *Upper limit:* fall in *Pinus* and Cyperaceae, and moderate increase in Apiaceae.
Ls1 51.25- 63.5	Poaceae-*Pinus*-Cyperaceae	AP/T ratio steady at 45-40. From this zone onwards, Cerealia, *Secale* and *Juglans* are recorded. *P. lanceolata* consistently present at low levels. *Upper limit:* Decline of *Pinus* and moderate increase in Rosaceae and Ranunculaceae.

Pla de Croutz at 1853 m in the Soulcem valley (Fig. 5). In this profile like in the previous, charcoal particles are present but are not abundant. At some levels charcoal is absent (27.5 to 14.6 cm and 10 to 1 cm). Nine LPAZs are recognised (Table 4).

As previously described, this sequence is characterized by low AP/T ratios and the regular presence of indicators of human activity and open vegetation. A substantial change is recorded at 31 cm after which the AP/T ratio falls below 50%. In this case, the most important changes in the pollen diagram are not correlated with increased charcoal. It is suggested that from 2000 B.P. onwards, fires within the valley occurred essentially at altitudes lower than Pla de Croutz, the forest having been already destroyed at the altitude of the site. The curve of *Olea* is continuous from 22 cm but the pollen is present from the bottom of the sequence.

Quioules valley

Jasse de Ranques at 1430 m in the Quioules valley (Fig. 6). Nine LPAZs are recognised (Table 5). The data indicate the presence of a fir forest in which beech develops after 5000 B.P. (R1-R3). It is only shortly after 3210±70 B.P. (1637-1312 cal. B.C.), i.e. during the Bronze Age, that *Fagus* extends (R3), *Abies* retreats simultaneously, anthropogenic indicators appear and heathlands expand (cf. Ericaceae curve, R5, R6). After 900±90 B.P. (cal. A.D. 1000-1223), i.e. between the 11th and 13th centuries, the destruction of the fir-beech forest proceeds rapidly.

Pla du Quioules at 1600 m in the Quioules valley (Fig. 7). Seven LPAZs are recognised (Table 6). The lowermost part of the profile indicates an *Abies*-dominated forest. Low NAP as well as the scarcity of pollen of apophytes and anthropogenic indicators may indicate reduced local human impact. The destruction of the forest occurs from the time covered by zone R3 to about 650±80 B.P. (1247-1432 cal. A.D.), i.e. between the 13th and the 15th centuries. *Abies* is first affected and then the other trees. Subsequently, the curves for *Abies* and *Fagus* rise again, and *P. lanceolata* and later *Fagopyrum* are recorded. In the upper part of the pollen diagram a good correlation exists between the abundance of pollen of apophytes and anthropogenic indicators and the destruction of the forest.

Pla de la Sabine at 1755 m in the Quioules valley (Fig. 8). Seven LPAZs are recognised (Table 7). The profile covers the last millennium. During the Middle Ages, the recurrent deforestations that affected pine and fir are followed by the expansion of *Betula*. The ^{14}C date 720±200 B.P. (864-1662 cal. A.D.) relates to this period but there

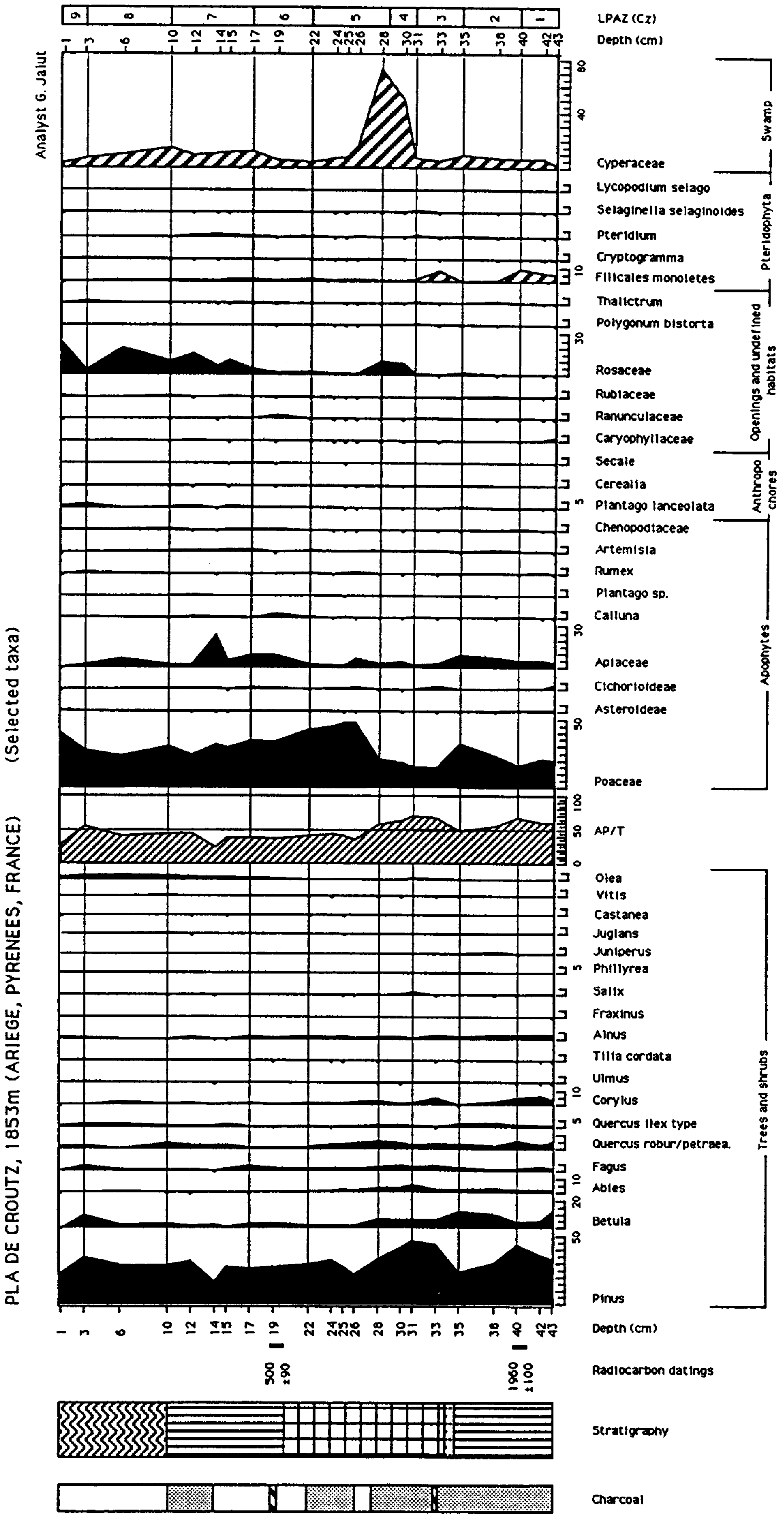


Fig. 5. Pollen diagram from Pla de Croutz

Table 4. Description of the local pollen assemblage zones in the profile Pla de Croutz

LPAZ/ Depth (cm)	LPAZ name	Main features of the LPAZ
Cz9 1- 3	Poaceae-*Pinus*-Rosaceae-Cyperaceae	Decrease in the AP/T ratio and the values of *Pinus, Betula* and *Fagus*. Increase in Poaceae and Rosaceae.
Cz8 3- 10	*Pinus*-Poaceae-Rosaceae-Cyperaceae	Regular presence of Chenopodiaceae, *Rumex* and *Cryptogramma*. Presence of *Juglans*. Slight increase in *Fagus* at the end of the zone. *Upper limit:* decrease in *Pinus, Betula* and Fagus and increase in Poaceae and Rosaceae.
Cz7 10- 17	Poaceae-*Pinus*-Cyperaceae-Rosaceae-Apiaceae	Slight decrease in *Alnus* and *Fagus*, increase in Rosaceae and abrupt change in Apiaceae. *Upper limit:* slight increase in Rosaceae and Apiaceae, and decrease in Cyperaceae and Poaceae.
Cz6 17- 22	Poaceae-*Pinus*-Apiaceae	Beginning of a continuous curve for *Olea*, increase in Apiaceae, continuous curve for *Calluna* and decrease in Poaceae. *Upper limit:* increase in Rosaceae and *Artemisia*, and decrease in *Fagus*.
Cz5 22- 28	Poaceae-*Pinus*-Cyperaceae	Continuous curve for *P. lanceolata* begins in the upper part of the zone. First records for *Secale, Juglans* and *Castanea*. Slight decrease in *Abies* values. *Upper limit:* increase in Apiaceae, *Calluna* and Ranunculaceae, and decrease in Poaceae.
Cz4 28- 31	Cyperaceae-*Pinus*-Poaceae-Rosaceae	Dominance of Cyperaceae and increase in Rosaceae, *Pinus* lower than 30% and first records for Cerealia. *Upper limit:* decrease in Cyperaceae and Rosaceae, and increase in Poaceae.
Cz3 31- 35	*Pinus*-Poaceae-*Betula*-Cyperaceae	Decline of *Betula*, Poaceae and Apiaceae, and first records for *Vitis*. Small in crease in *Abies* at the end of the zone. *Upper limit:* increase in Cyperaceae and Rosaceae, and decrease in *Pinus*.
Cz2 35- 40	*Pinus*-Poaceae-*Betula*-Apiaceae	Increase in *Betula* and Poaceae and presence of *Juniperus*. *Upper limit:* decrease in Poaceae and *Betula*, and increase in *Pinus*.
Cz1 40-43	*Pinus*-Poaceae-*Betula*-Cyperaceae-Apiaceae	Dominance of *Pinus* (40-30%) and presence of *P. lanceolata* and *Rumex*. *Upper limit:* increase in Poaceae and decrease in *Pinus* and occurrence of *Juniperus*.

is no precise information on the duration of the events recorded. A progressive increase of the herbaceous taxa occurs but deforestations do not completely destroy fir and pine regularly regenerates. It is only at the top of the profile that the complete destruction of the fir-beech forest is recorded. All trees, except pine, seem to be affected. The slight increase in values of *P. lanceolata* and Chenopodiaceae indicates the development of pasture. It may be assumed that the increases in *Quercus* and Cerealia, which are correlated with the deforestations, are due to better transport and hence increased deposition of these taxa following the opening-up of the forest.

Discussion

Using the criteria indicated above, the six pollen diagrams have been correlated (Fig. 9). Three mains phases can be distinguished: the Bronze Age and the Iron age period, the Roman period and the Early Middles Age, and the High Middle Ages to present.

Bronze Age and Iron Age

In the valley of Quioules, at Jasse de Ranques, *Abies* values of between 20 an 40% indicate that fir forests dominated. Using estimated ages (EA) based on the depth/age ratio, it is deduced that, between c. 4200 B.P. (EA) and 3210 B.P., beech is poorly represented and apophyte pollen are rare. There are records for *P. lanceolata* at c. 3600-3500 B.P. (EA). We can conclude that, at that time, there is little local human impact at this elevation. Human impact becomes more obvious from the beginning of the Bronze Age (3210±70 B.P., cal. B.C. 1637-1312). Because of the favourable conditions provided by the flat topography above 2000 m and the low tree cover, we can suppose, as demonstrated in Cerdagne for comparable altitudinal and topographic zones (Galop, in preparation), that pastoral farming in the Quioules valley began in the lower reaches of the valleys and also in these more favourable zones at higher altitudes where, however, farming was restricted.

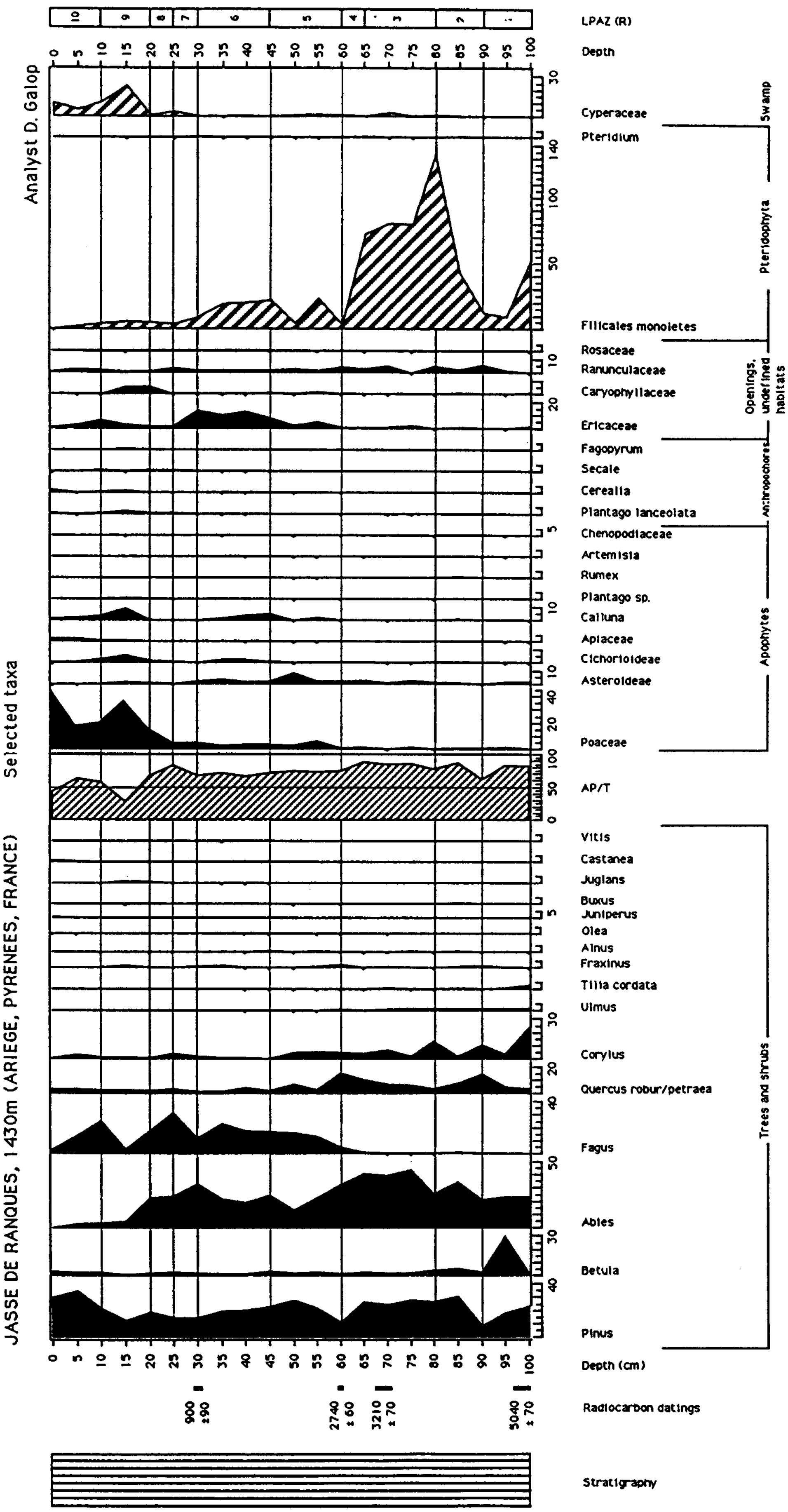


Fig. 6. Pollen diagram from Jasse de Ranques

Table 5. Description of the local pollen assemblage zones in the profile Jasse de Ranques

LPAZ/ Depth (cm)	LPAZ name	Main features of the LPAZ
R10 0- 10	Poaceae-*Pinus-Fagus*-Cyperaceae	Increase in *Pinus* and Poaceae, fall in *Fagus* and decrease in *Abies*.
R 9 10- 20	Poaceae-*Fagus-Pinus*-Cyperaceae	Decline in *Abies, Fagus* and *Pinus*, first records of *Castanea* and increase in Cyperaceae, Ericaceae, *Calluna* and Cichorioideae. Moderate increase in *P. lanceolata* and Cerealia. *Upper limit:* decrease in *Fagus* and increase in *Pinus*.
R8 20- 25	*Fagus-Abies-Pinus*-Poaceae	Fall of *Fagus* and increase in Poaceae. *Upper limit:* Decline in *Abies, Fagus* and *Pinus*, and increase in Poaceae and Cyperaceae.
R7 25- 30	*Fagus-Abies-Pinus*-Ericaceae-Poaceae	Decrease in *Abies*, simultaneous increase in *Fagus* and fall in Ericaceae. *Upper limit:* decline in *Fagus* and increase in Poaceae.
R6 30- 45	*Abies-Fagus-Pinus*-Ericaceae-*Calluna*	Progressive decrease in *Pinus*, increase in *Abies* and *Fagus*, *Juglans* consistently present and Ericaceae well represented. Cerealia, including *Secale* and *P. lanceolata* present. *Upper limit:* decrease in *Abies* and Ericaceae, and increase in *Fagus*.
R5 45- 60	*Abies-Pinus-Fagus-Quercus-Corylus*-Ericaceae-Poaceae	Increase in *Pinus* and decrease in *Abies* and *Quercus*. Synchronous increase in *Fagus*. Decrease in *Corylus* at the end of the zone. *Upper limit:* first records for *Secale* and *Juglans*.
R4 60- 65	*Abies-Pinus-Quercus-Fagus*	Decrease in *Pinus* and *Abies*, increase in *Fagus* and *Quercus* and sharp decline in Filicales. *Upper limit:* decrease in *Abies* and *Quercus*, and increase in Poaceae, Ericaceae and *Calluna*.
R3 65- 80	*Abies-Pinus-Quercus-Corylus*-Ericaceae	Optimum of *Abies* (45%), regular presence of *Fagus*, decrease in *Corylus* and Filicales, and first occurrence of *P. lanceolata*. *Upper limit:* decrease in *Pinus* and *Abies*, and increase in *Fagus*.
R2 80- 90	*Abies-Pinus-Quercus-Corylus-Betula*	Increase in *Pinus* and *Abies*, decrease in *Quercus*, first occurrence of *Fagus*, low values for herbaceous taxa and strong increase in Filicales. *Upper limit:* increase in *Abies* and decrease in *Corylus* and Filicales.
R1 90-100	*Abies-Pinus-Betula-Corylus-Quercus*	Decrease in *Pinus, Corylus* and *Tilia*, synchronous increase in *Quercus*, mid-zone peak in *Betula* and *Abies* at a steady 25%. *Upper limit:* increase in *Pinus* and *Abies*, and first presence of *Fagus*.

Before 3000 B.P. (EA), *Fagus* has a higher representation in the Soulcem valley than in Ranques (Quioules valley), but the percentages of *Abies* are low (around 5%) while apophytes are well represented and Cerealia pollen is present at c. 3500 B.P. (EA). These data are confirmed by the pollen analysis of another sequence from the north of Pla de Soulcem, at the foot of the abrupt western slope (Esteban-Amat, 1982, unpublished work; Jalut et al. 1984). Around 4800-4600 B.P., the AP/T ratio is lower than 50%, apophytes are well represented, *Fagus* pollen is sporadically present and the *Abies* values are between 2.5 and 5%. It is clear that, at that time, there was already human impact in the Soulcem valley but the level of impact in these two neighbouring valleys was not comparable.

Because of the different time spans represented by the sequences, comparisons similar to those made above for the period 3000-5000 B.P. are not possible. The pollen diagram of Jasse de Ranques, however, contains information relating to the relationship between *Abies* and *Fagus*. In the context of the regional history of *Fagus*, the expansion of this tree at Ranques (3210±100 B.P.) seems particularly late, which reinforces the hypothesis of a late human occupation of this valley.

At Freychinede, about 22 km to the north-west, the dates for the expansion of *Fagus* as given by four different samples, each consisting of 1-cm-thick sediment slices, lie between 3980±110 and 3730±250 B.P. (Jalut et al. 1982; Fig. 1). In a new analysis of material from the same coring location, the first occurrence of *Fagus* and the beginning of its expansion are dated to 4050±150 B.P. by Reille (1993a, b). Though the sample in question was thick (>10 cm), this age corresponds with the previously available dates as well as the new date from Estagnon 1 (3970±70 B.P., Reille 1993a), which lies at c. 750 m to the south-east of the Etang de Lhers coring

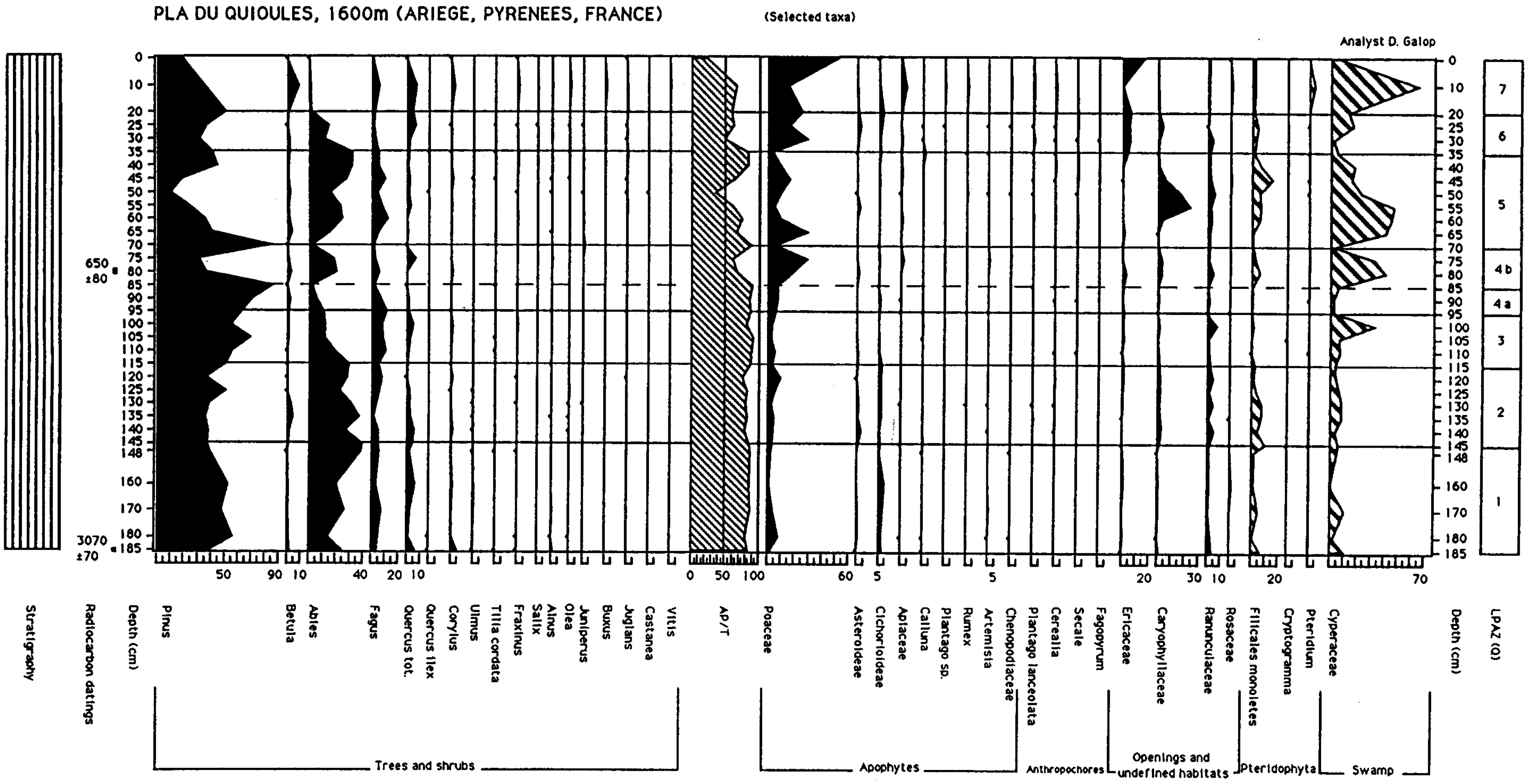


Fig. 7. Pollen diagram from Pla de Quioules

Table 6. Description of the local pollen assemblage zones in the profile Pla du Quioules

LPAZ/ Depth (cm)	LPAZ name	Main features of the LPAZ
Q7 0- 20	*Pinus*-Poaceae-Cyperaceae-Ericaceae	Decrease in *Pinus*, *Abies* very low, *Fagus* <10%, small increase in *Betula* and *Corylus* and larger increases in *Quercus*, Poaceae, Cyperaceae and Ericaceae.
Q6 20- 35	*Pinus*-Poaceae-*Abies*-Cyperaceae-Ericaceae	Sharp decrease in *Abies* and slight decrease in *Fagus*, increase in *Pinus*, *Quercus* and apophytes, and presence of *Fagopyrum*. *Upper limit:* decrease in *Pinus* and Poaceae, and increase in Cyperaceae.
Q5 35- 70	*Pinus*-*Abies* Cyperaceae-*Fagus*-Poaceae	Sharp decrease in *Pinus*, increase in *Abies* and *Fagus*, regular presence of *Juglans*, *P. lanceolata* and *Secale*. *Upper limit:* fall in *Abies* percentages and increase in Poaceae.
Q4 b 70- 85	*Pinus*-Cyperaceae-Poaceae-*Abies*	Abrupt decline in *Pinus* then increase at the end of the zone, opposite changes in *Abies*, and increase in Poaceae and Cyperaceae. *Upper limit:* decrease in *Pinus* and increase in *Abies* and *Fagus*.
Q4 a 85- 95	*Pinus*-Poaceae-*Fagus*-*Abies*	Decrease in *Abies* and *Fagus* percentages, increase in *Pinus*. *Upper limit:* decrease in *Pinus* and increase in *Abies*, Poaceae and Cyperaceae.
Q3 95-115	*Pinus*-*Abies*-*Fagus*-Cyperaceae	Increase in *Pinus* and *Fagus*, strong decrease in *Abies* percentages and first records of *Secale*. *Upper limit:* decrease in *Abies* and *Fagus*.
Q2 115-145	*Pinus*-*Abies*-*Fagus*-*Quercus*-*Betula*	Decrease in *Abies* and *Quercus*, small rise in *Betula*, and occurrence of *P. lanceolata* and Cerealia. *Upper limit:* increase in *Pinus* and decrease in *Abies*.
Q1 145-185	*Pinus*-*Abies*-*Fagus*- *Quercus*	Increase in *Abies*, *Fagus* and *Quercus* stable and high AP/T ratio. *Upper limit:* decrease in *Abies*, small rise in *Betula* , Asteroideae and Caryophyllaceae.

(Kenla and Jalut 1979). However, at the site of Argentiere in the same area (Galop, in preparation) (Fig. 1), a 5-cm thick peat sample gave a date of 4590±60 B.P. for the expansion of *Fagus*.

Taking into account these dates and their standard errors, it can be concluded that, on the one hand, the same event, namely the expansion of *Fagus*, begins at clearly different dates at the various sites. Given the geographically restricted area, it can be assumed that climatic conditions were largely comparable throughout the area. On the other hand, it is clear that, in all cases, these levels in the profiles correspond to increases in anthropogenic indicators.

This reinforces the opinion that, as recorded at many sites, *Fagus* began to extend in the *Abies*-dominated forests at c. 5000 B.P. This was due largely to a change in climate at about this time. But this remained a limited development until the beginning of human impact. The early clearances of fir were mainly responsible for the development of beech. Our results demonstrate that this development occurred at different times in the various sites, and that these chronological differences are dictated by the degree of human activity in the immediate vicinity of the individual sites. Topography, location and density of human communities as well as economic constraints have determined the timing of the first human impact on the mountain forests. This explains the regional asynchronism in the development of beech.

Human impact differs not only between valleys but also between sites. At Soulcem, the fine particles of charcoal observed near 3000-2900 B.P. (EA) (Sm2, Fig. 9), correspond with a moderate increase in apophytes which is followed by consistently lower values. The *Abies* curve remains stable and that of *Fagus* rises slightly up to about 2300 B.P. (EA) (Sm2-Sm3 boundary). The anthropochores are rare. Near 2300 B.P. (Sm2-Sm3 boundary), the charcoal curve rises again which corresponds to a decrease in *Corylus* and *Pinus* values. The charcoal particles, especially where they are very abundant (232 to 222 cm), demonstrate clearly the early use of the forest in this valley.

In Pla de Quioules, the representation of some apophytes (Cichorioideae) increase between ca. 3000 and 2800 B.P. (EA) (beginning of Q1; Fig. 7), and then decline, while *Abies* continues to expand until c. 2000 B.P. (EA) (Q1/Q2 boundary). At Jasse de Ranques, on the other hand, the opposite occurs. Apophytes and anthropochores (Cerealia) are particularly well represented at c. 2300 B.P. (EA) (depth 50 cm, Fig. 6) and, at the same time, *Abies* declines and *Fagus* develops. In the

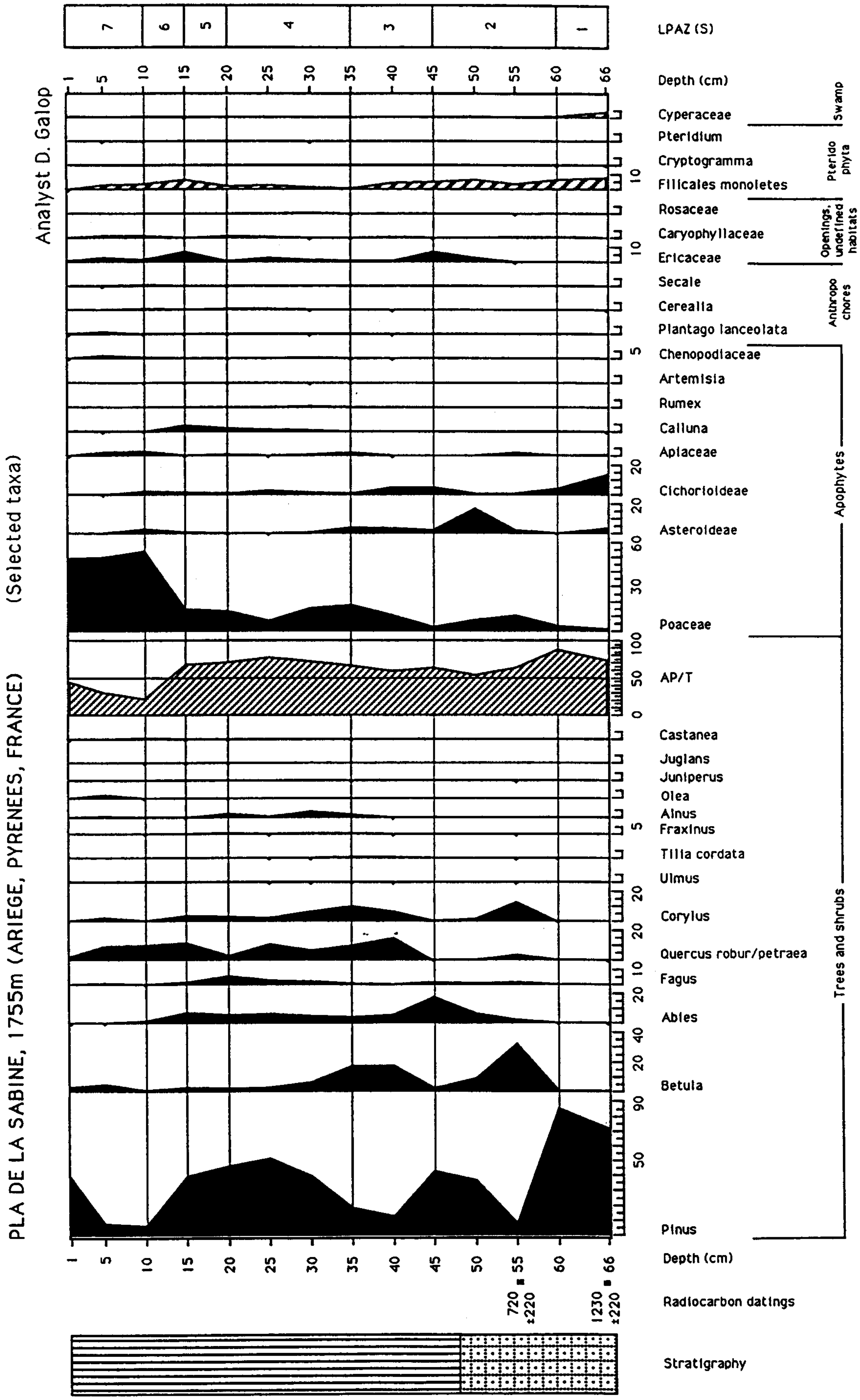


Fig. 8. Pollen diagram from Pla de la Sabine

Table 7. Description of the local pollen assemblage zones in the profile Pla de la Sabine

LPAZ/ Depth (cm)	LPAZ name	Main features of the LPAZ
S7 0- 10	Poaceae-*Pinus*-*Quercus*	Increase in *Pinus* at the end of the zone, very low values for *Abies* and *Fagus* and small increase in *P. lanceolata* and Chenopodiaceae.
S6 10- 15	Poaceae-*Pinus*-*Quercus*-Ericaceae-Calluna	Low values for *Pinus*, decrease in *Abies*, *Fagus* and *Corylus*, regular presence of *Castanea*, *Secale* and Cerealia. Sharp increase in Poaceae. *Upper limit*: decrease in *Abies* and increase in *Betula* and Chenopodiaceae
S5 15- 20	*Pinus*-Poaceae-*Quercus*-*Abies*-Ericaceae	Decrease in *Pinus* and *Fagus*, increase in *Quercus*, presence of *Juglans* (isolated grains) and increase in Ericaceae. *Upper limit:* decrease in *Pinus* and *Abies* values, and increase in Poaceae.
S4 20- 35	*Pinus*-Poaceae-*Quercus*-*Abies*-*Fagus*	Increase in *Pinus* and *Fagus*, decrease in *Betula* and *Corylus*, presence of *Castanea* and increase in Cerealia. *Upper limit:* decrease in *Pinus* and *Fagus*, and increase in Ericaceae.
S3 35- 45	*Betula*-*Pinus*-Poaceae-*Quercus*-*Corylus*	Increase in *Betula, Corylus and Quercus,* decrease in *Pinus* and *Abies* and very low values for *Fagus*. Isolated records of *P. lanceolata.* *Upper limit:* increase in *Pinus* and decrease in *Betula* values.
S2 45- 60	*Pinus*-*Betula*-*Corylus*-*Abies*-Poaceae	Abrupt fall in *Pinus* at the beginning of the zone and parallel increase in *Betula* and *Corylus*, small increase in *Quercus* and *Abies*, low values of *Fagus*. Increase in Poaceae, Apiaceae and then Ericaceae. *Upper limit:* fall in *Pinus* and *Abies* and increase in *Betula, Corylus* and *Quercus*.
S1 60- 66	*Pinus*-Cichorioideae Asteroideae-Poaceae	Dominance of *Pinus* (>70%), pollen of other trees not recorded, slight increase in Poaceae, decrease in Compositae and presence of Cerealia. *Upper limit:* fall in *Pinus* and increase in *Betula* and *Corylus.*

valley of Quioules, no traces of charcoal during this period are found in the sediments of the studied sites. Charcoal is recorded only during the historical period.

The Roman Age and the Early Middle Ages

From the Gallo-Roman period (50 B.C. to the 4th century A.D.), and more particularly at the beginning of the Middle Ages (10th and 11th centuries), an increase in human impact is recorded in most sites, particularly at Soulcem, Croutz, Ranques and Quioules. Anthropochores are present everywhere except in Pla de la Sabine. At Soulcem (Sm4, cal. A.D. 680-1022, Fig. 3) a pronounced decline in tree pollen occurs during the second half of the Early Middle Ages (Early Middle Age: 5th to 10th centuries). It corresponds with the presence of abundant charcoal particles between 158 and 150 cm. At Pla de Croutz, charcoal particles are also regularly present during the same period with a particular abundance at 33 cm which is considered to correspond with the Early Middle Ages.

In the Quioules valley a fir-beech forest is present at c. 1400-1500 m altitude. If open areas exist (cf. Ericaceae and *Calluna* curves), the valley is still forested as demonstrated by the values of *Abies* and *Fagus* at Ranques and Quioules. At Pla de la Sabine, at an altitude favourable for fir, pollen of *Abies* is rare and *Pinus* pollen dominates with Compositae. This allows us to suppose that the first strong human impact in the Quioules valley occurred in its upper part. This is confirmed by the very strong increase in pastoral activities recorded in the neighbouring site of Sauzet (2000 m) between the 7th and 10th centuries (Galop, in preparation)

From the High Middle Ages to Present

During this period human impact is recorded everywhere, but it is also the time when with the greatest differences occur in the forest history of the two valleys. The historical data allow the reasons of these differences to be understood. They are due to the interaction of natural, demographic and chiefly economic factors.

In the valley of Soulcem, the low values of *Abies*, *Fagus* and the AP/T ratio indicate an open landscape while anthropogenic indicators emphasise the important role of pasture. The consistent presence of charcoal particles in the sediments of the studied sites confirms the strong human impact in the valley. This charcoal dust can be considered as the result of pastoral fires and/or charcoal production on the slopes.

For this valley there is good agreement between palynological and historical data relating to the Middle Ages. A dense population occupied the valley up to 1600 m altitude. The basis of the Vicdessos economy was, on one hand, agriculture and grazing, and, on the other hand, metallurgy was important. In these circumstances the forests of the valley of Soulcem were destroyed at an early date. Historical data record the development of metallurgy during the 13th century, but archaeological

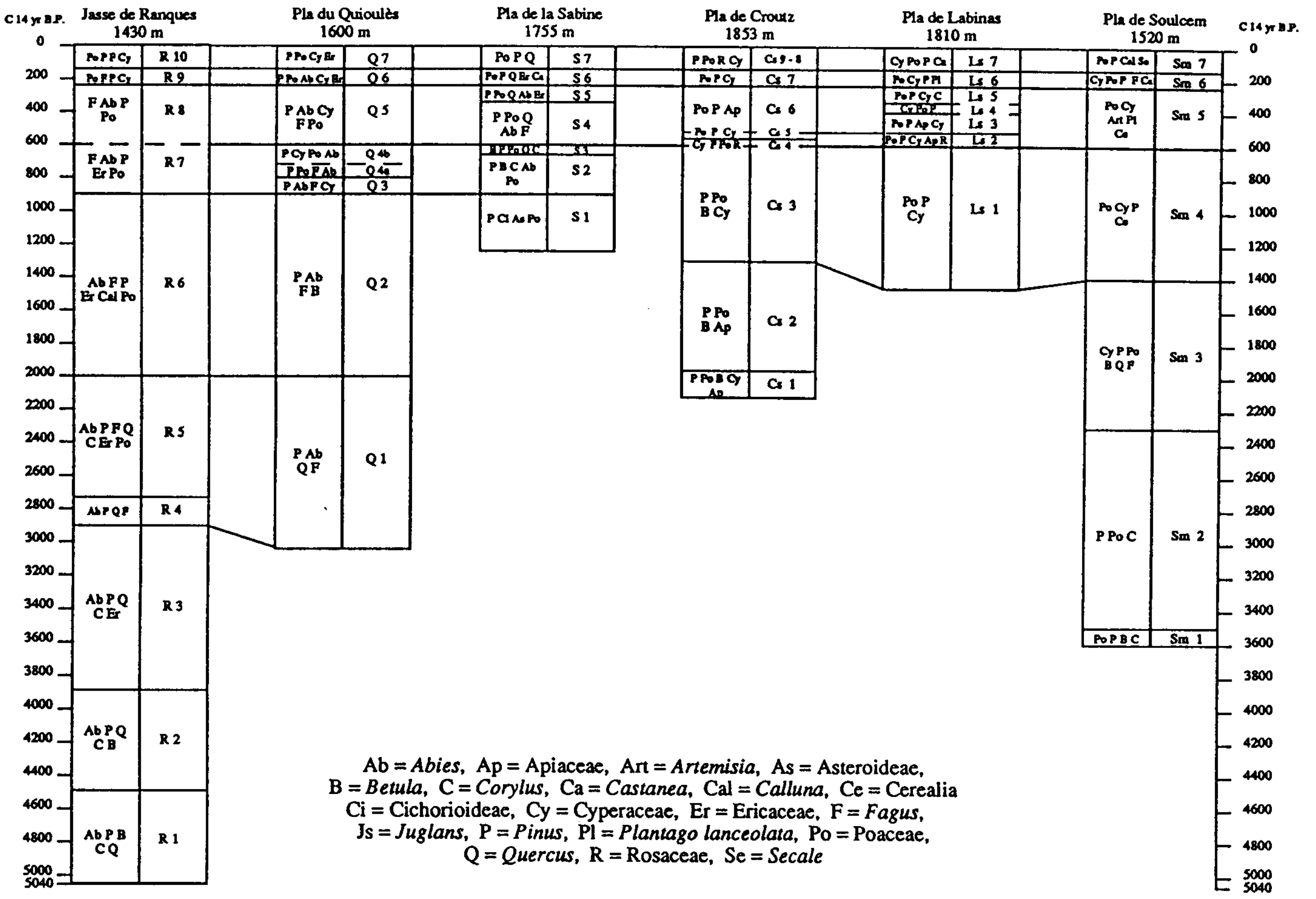


Fig. 9. Time-space correlation of local pollen assemblage zones

data demonstrate that the beginning of a local metallurgical industry is clearly older (Gallo-Roman period) (Fig. 10).

Human activity, as described above, was responsible for the destruction of the forest, particularly fir, as recorded in Pla de Croutz and Soulcem at c. 600 B.P. (EA). The increase in charcoal particles and anthropogenic indicators suggests an increase of the human impact during this period. Around the 15th-16th centuries, the installation of a forge between Pla de Soulcem and Pla de Labinas (Davasse 1991; Fig. 2) was responsible for the final deforestations (charcoal particles are abundant in the sediments corresponding to this time). However, on the basis of the palynological data, it seems that relict stands of beech-fir forest still existed at c. 300-200 B.P. (15th-18th centuries). This is supported by the remains of charcoal kilns which have yielded charcoal of fir, beech and pine which have been dated. The existence of stands of these trees between the 16th and 18th centuries is therefore beyond doubt (Davasse 1991).

Historical data indicate that, at the end of the 17th century, the valley was nearly completely deforested and that there was much grazing (Réformation de L. de Froidour 1669; Archives of Ariège). This agrees, on the one hand, with the increase in apophytes and anthropochores in the upper levels of the pollen diagrams, and, on the other hand, with the abundance of *orrys*, i.e. pastoral huts built with stones which are found all along the valley. During the 18th century, an increasing population which coincided with the decline of forges was responsible for increased grazing and greater demand for wood. The last stands of trees of the valley were cut down during this time, as well as many other forests in Vicdessos so that only reduced beech coppices exist today (Davasse and Galop 1990).

In the present century, there has been a decline in grazing pressure but grazing still continues to be important. This partly explains why the treeless landscape has persisted while, in the other neighbouring valleys of Ariège, and particularly in the Quioules valley, forest regeneration is taking place. While human impact may be the main factor affecting vegetation, especially in the Soulcem valley, climatic factors such as the *foehn* effect also be playing a role in the failure of woodland to develop.

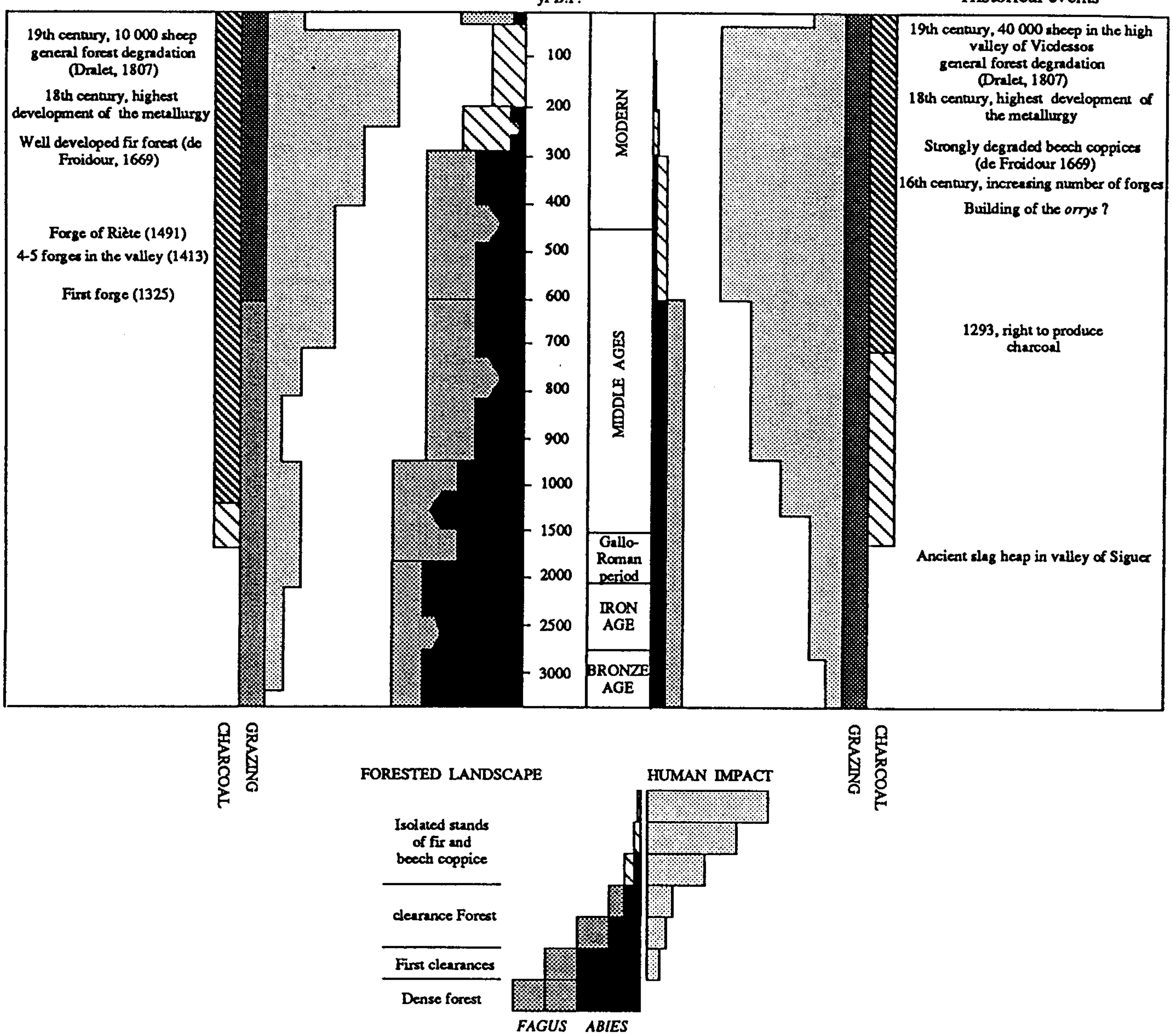


Fig. 10. Diagrammatic representation of forest and land-use history in the valleys of Quioules and Soulcem

In the Quioules valley, during the same period, i.e. beginning at c. 1000 B.P., the three studied sites record an increase in apophytes and anthropochores due to increased impact which was responsible for the reduction of the forest cover at all altitudes. At the same time, the first evidence of charcoal production, related to the development of metallurgy at the beginning of the Middle Ages, are recorded in the valley. Charcoal production is demonstrated at Pla de la Sabine between the 11th and 12th centuries (930±40 B.P., cal. A.D. 1022-1199, Galop 1992). This corresponds to a time when the anthropogenic indicators are still rare. The study of charcoal from charcoal kiln preserved in the peat bogs shows the presence of fir at 1750 m during this time.

Between the 13th and the 14th century (near 600 B.P., Q4a and 4b, Fig. 7), the pollen data indicate an increase in human impact throughout the valley which is confirmed by the historical data. It corresponds with an increase in metallurgical activity in the valley of Aston of which the Quioules valley is the most important branch. From the 15th until the 17th century, the forests of the valley were devoted to metallurgy and four large forges were built, especially noteworthy being the forge of Riete built in 1491 at the bottom of the valley of Quioules (Fig. 2). A consequence was the expansion of charcoal production in the whole valley of Quioules and also at higher than 2000 m. Despite this intensive forest exploitation, the palynological data indicate the persistence of a forest cover, and the scarcity of the grazing indicators leads us to suppose that pastoral farming was limited to the treeless zones at high altitude or in clearings. Fir was present near the studied sites up to about the 17th-18th century as described in 1669 by the General Forestry Surveyor Louis de Froidour, who indicates that the fir forest of Aston was one of the most beautiful in Ariège. Pine was also present and, in the same area, charcoal kilns dated to 230±40 and 320±50 B.P. (Bonhote, in Galop 1991) not only confirm the exploitation of the forests but also their persistence to the beginning of the 18th century.

On the basis of the historical data, it seems that the maximum destruction of the forest occurred when metallurgy was at its optimum during the 18th century. This abrupt destruction in less than one century is recorded in the pollen diagrams by an increase in apophytes and anthropochores which demonstrate the expansion of grazing. The archives indicate that, the local landlord, who also owned the forges, favoured the practice of transhumance pasture as a means of maintaining income as metallurgy went into decline (Chevalier 1956).

The recent history of the valley of Quioules is intimately linked to the economy of a manorial land essentially devoted to metallurgy. The low density of population, with villages and cultivated areas more or less confined to the bottom of the valley and forest use being determined by the owner was responsible for the presence of a well developed forest up to the 18th century, which is quite different from the situation in the Soulcem valley. It is only in the eighteenth century that the economic system based on metallurgy led to the destruction of the forest, the disappearance of fir and the extension of degraded beech coppices. From this period onwards, it can be assumed that repeated pollarding hindered the growth and flowering of beech which explains the scarcity of *Fagus* pollen which does not necessarily signify the absence of the tree. Up to the beginning of the 20th century, grazing maintained the forest in a degraded state. Then, because of the decrease in population and pasture, pine was able to spread particularly at low altitude, and fir reappeared in the valley (Fig. 2).

Conclusions

The palynological and historical studies of two neighbouring valleys provide new information on the forest history of this central Pyrenean region. The human role in the extension of beech during the prehistoric period is well known for many years (Kenla and Jalut 1979; Jalut 1984; Jalut et al. 1982, 1988). It is clear from the palynological data presented here that human impact became stronger and reaches its maximum in the last millennium. This last stage of the Pyrenean forest history, which saw the final shaping of the present-day landscape was, up to now, rarely considered in palynological studies within the region (Kenla and Jalut 1979; Galop 1991).

The first substantial differences in the vegetation and land-use history of the Quioules and Soulcem valleys are observed from 3000 B.P. onwards (Fig. 10). It is assumed that these differences arise from the interaction of several natural factors. The topography of the Vicdessos valley, which made the area readily accessible, was probably a determining factor for early settlements. At the same time, the Quioules valley, narrower and more difficult to penetrate, was subject to only reduced human impact and its forest cover stayed dense. The difference in beech expansion in these two neighbouring valleys can be partly explained by the topography and the different levels of human activity. A synchronous beech expansion within the fifth millennium B.P. is an untenable hypothesis.

For the two valleys in question, differences became more pronounced during the Middle Ages and the socio-economical factors allow two types of forest history to be distinguished. On one hand, developments in the Quioules valley were largely influenced by the presence of a large manorial domain which was devoted to metallurgy from the beginning of the Middle Ages onwards. Low population pressure and restricted rights of forest use, probably connected with a forest management favourable to metallurgy, were responsible for forest protection. Then, at the end of the Middle Ages, over-exploitation of the forest as well as an increase in pasture interrupted this equilibrium and led to forest destruction. In the Soulcem valley, on the other hand, a communal agro-pastoral economical system prevailed which was characterized by important rights of use given to the local population. Within the context of this rural economy, systematic use of the forests for charcoal and lumber, and pastoral and agricultural practices, were responsible for the early reduction and later the destruction of the forests.

Despite asynchronisms linked to different systems of exploitation in the various areas, human impact has resulted in some fundamental changes in plant distribution. The disappearance of fir and pine forest favoured the development of heaths and pastures in these deforested areas (Fig. 2) while, taking advantage of the decrease of *Abies*, *Fagus* has progressively become the major species of the mountain forest. This disappearance of the altitudinal forest is anthropogenic in origin, and it has caused an artificial lowering of the timber-line and other ecotones. Pine is at present regenerating at between 1600 and 2000 m altitude which constitutes the upper part of the potential area of the fir forest.

The present results demonstrate that, for the last four millennia, although human impact is always a determining factor of forest history, other factors and processes normally also play important roles. Due to the diversity of the human activities depending on various socio-economical factors, we can observe in areas which lie in close proximity and experience comparable climatic conditions different types of forest history. The case of the Quioules and Soulcem valleys clearly demonstrates this.

This study shows that recent mountain forest history is not uniform and that the changes observed in a forest cover cannot be generalized either at the scale of a geographic region or of a whole mountain massif. Only detailed palynological studies allow the local differences to be perceived. For the historical period, as frequently emphasised (Nunez and Vuorela 1978) the study of the archives is fundamental to understand the social phenomena which are largely responsible for the present-day features of the upland landscape.

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